Development and Progress in Enabling the Photocatalyst TiO_2 Visible- Light-Active

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ABSTRACT

Photocatalytic oxidation (PCO) of organic contaminants is a promising air and water quality management approach which offers energy and cost savings compared to thermal catalytic oxidation (TCO). The most widely used photocatalyst, anatase TiO_2, has a wide band gap (3.2 eV) and is activated by UV photons. Since solar radiation consists of less than 4% UV, but contains 45% visible light, catalysts capable of utilizing these visible photons need to be developed to make PCO approaches more efficient, economical, and safe. Researchers have attempted various approaches to enable TiO_2 to be visible-light-active with varied degrees of success. Strategies attempted thus far fall into three categories based on their electrochemical mechanisms: 1) narrowing the band gap of TiO_2 by implantation of transition metal elements or nonmetal elements such as N, S, and C, 2) modifying electron-transfer processes during PCO by adsorbing sensitizing dyes, and 3) employing light-induced interfacial electron transfer in the heteronanojunction systems consisting of narrow band gap semiconductors represented by metal sulfides and TiO_2. There are diverse technical approaches to implement each of these strategies. This paper presents a review of these approaches and results of the photocatalytic activity and photonic efficiency of the end products under visible light. Although resulting visible-light-active (VLA) photocatalysts show promise, there is often no comparison with unmodified TiO_2 under UV. In a limited number of studies where such comparison was provided, the UV-induced catalytic activity of bare TiO_2 is much greater than the visible-light-induced catalytic activity of the VLA catalyst. Furthermore, VLA-catalysts have much lower quantum efficiency compared to the ~50% quantum efficiency of UV-catalysts. This stresses the need for continuing research in this area.

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